Direct Write Optical Waveguide Fabrication in organic films using a Heidelberg Laser Writer

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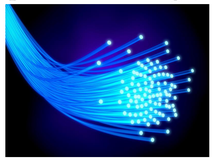
I. Project Objectives

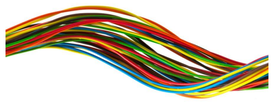
Goal: Optical Waveguide Devices.

- Material selection
- Fabrication
- Testing

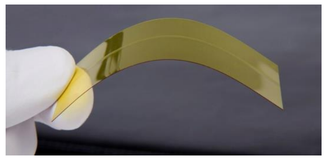
II. Motivation

- **Optical vs. Electronic Connections**
  -Higher data density due to the frequency of light
  -Lower power consumption
  -coplanar crossings, couplers, and splitters



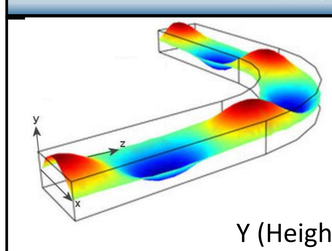


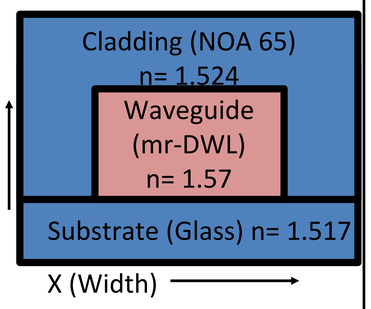
- **Organic/Printing**
  -simple/cheap
  -any surface



- **Example Applications**
  -Throw away biological sensors
  -Devices on flexible surfaces
  -optoelectronic devices

III. Theory



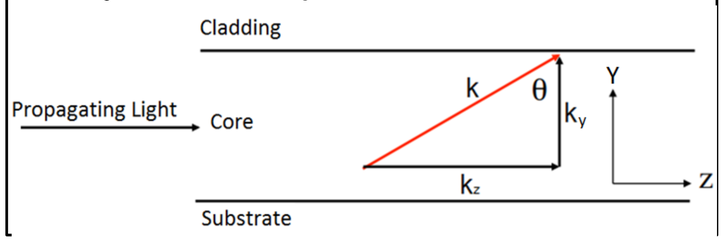


Critical Angle

$$\theta_{c2} = \sin^{-1}\frac{n_s}{n_w} \qquad \theta_{c1} = \sin^{-1}\frac{n_c}{n_w}$$

Calculating Resonant Modes

$$k_x = \frac{n_w \omega}{c}\cos\theta \qquad k_z = \frac{n_w \omega}{c}\sin\theta$$



IV. Material Selection

Waveguide (Photoresist Material)

Optical Properties- A high refractive index difference is good for coupling while a small difference is good at suppressing higher order modes.

Exposure Requirement- Heidelberg DWL 66+ (405nm) Negative resist

Cladding (NOA 65)- Index should match substrate

V. Fabrication

1) **Oxygen Plasma Surface Treatment**
2) **Coat mr-DWL-** 40mL/40mL dilution mr-DWL-5/Su-8 Thinner

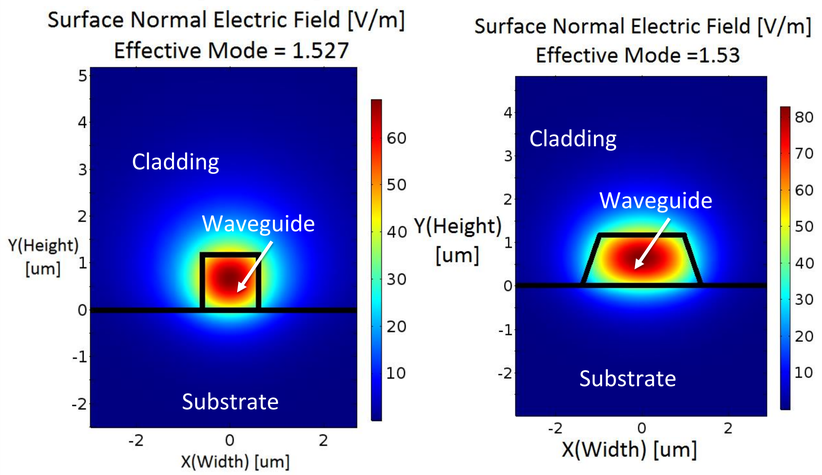
Spin Speed [rpm]	Thickness [um]
3000	1473
4000	1181
5000	1013

Post Application Bake	
Temperature [°C]	Time [min]
65	4

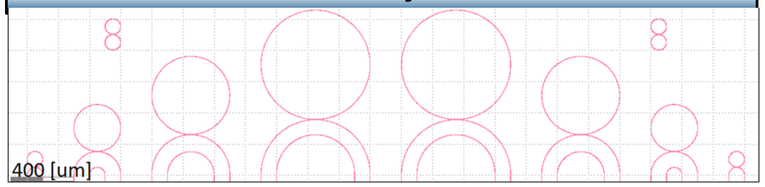
3) **Negative Exposure on Heidelberg**
   Important Parameters- 60% Intensity, 200mW Power
4) **Development in PGMEA 3.5 minutes.**
5) **Cladding NOA 65**
   Spin speed 3000rpm, UV flood cure 4.5[J/cm^2]
6) **Scribe/Cleave….**

VI. Simulation

Simulation in Comsol Software-Indexes used shown in Theory
Dimension square-1.2um width by 1.18um height.
trapezoid- top 1.6um, bottom 2.42um bv .79um height



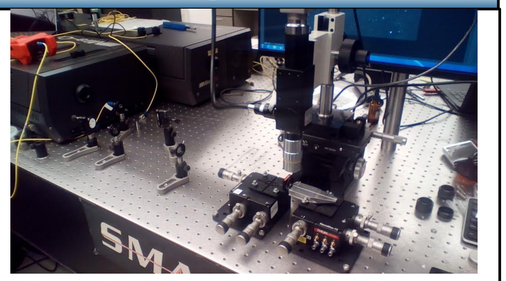
VII. Layout



VIII. Testing

Light Source
Fisher Scientific

Outpower 1mW min
Wavelength 650nm Typ



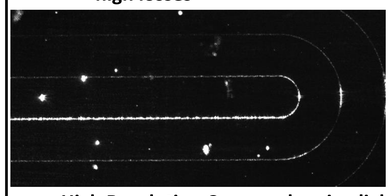
Focusing Lens stage
Lens is 4.5mm focal length
Initial beam alignment
Using X and Z controls

Sample Stage
Final coupling
Using movement in X,Y and Z
(no rotation controls)

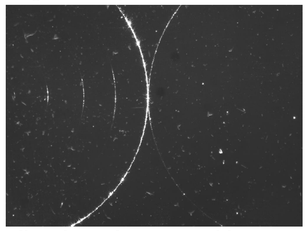
IX. Results

Visual results for nominal 1.2um devices.

50um radius bends have high losses



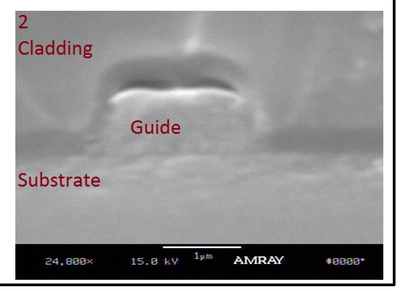
Waveguide coupled into a resonator



High Resolution Camera showing light traveling through a waveguide

Waveguides viewed with Secondary Electron Microscope

SEM Measurements [um]			
	1	2	3
Top	1.42	1.75	1.64
Bottom	2.35	2.41	2.50
Average Width	1.86	2.07	1.93
Average Height	0.79	0.79	0.79



X. Future

Short Course for direct write waveguides on the Heidelberg
Optimization of Processing
Expansion into additional devices.
Flexible Substrate.

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